ESC201T : Introduction to Electronics

Lecture 37: Sequential circuit design-1

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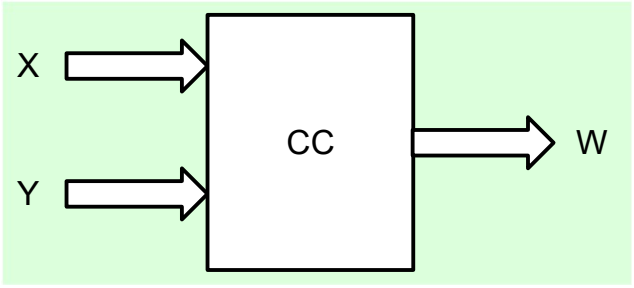
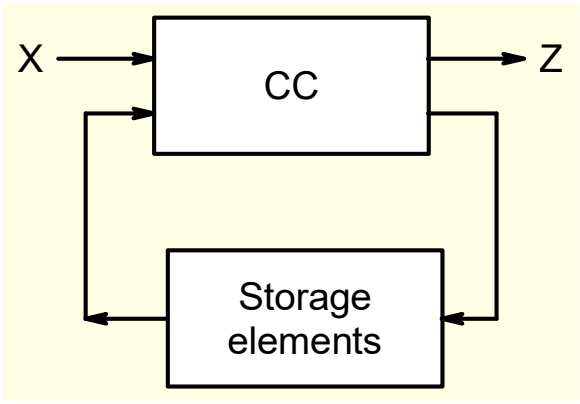
Digital Circuits

Combinational Circuits



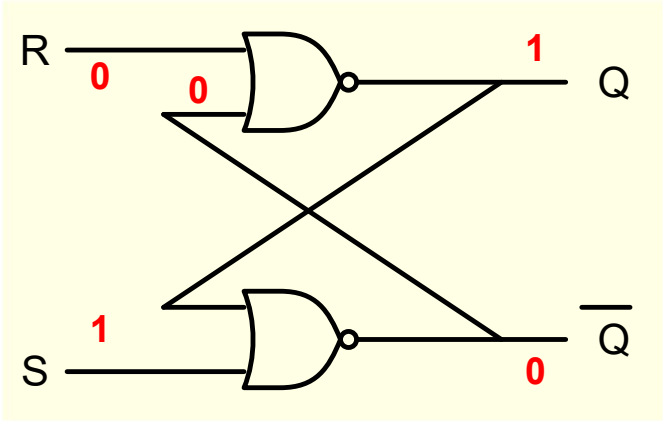
Output is determined by current values of inputs only.

Sequential Circuits



Output is determined in general by current values of inputs and past values of inputs/outputs as well.

NOR SR Latch

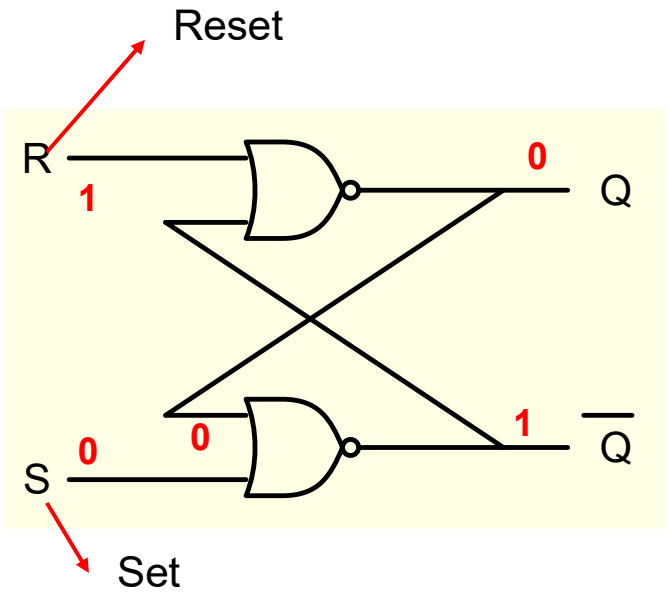


$Q = 1; \overline{Q} = 0$ Set State

$Q = 0; \overline{Q} = 1$ Reset State

S	R	Q	$\overline{Q}$	State
1	0	1	0	SET

NOR SR Latch

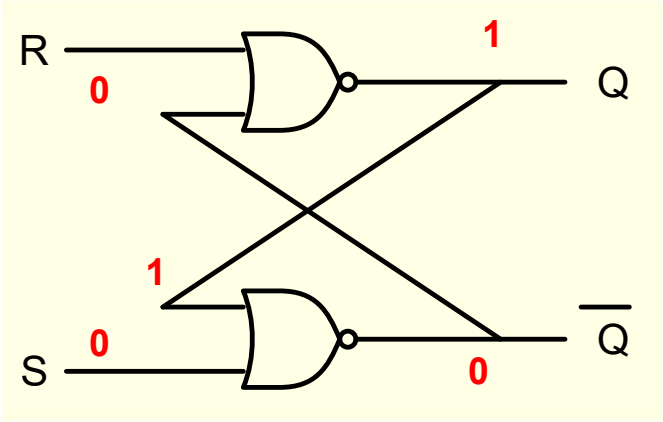


$Q = 1; \overline{Q} = 0$ Set State

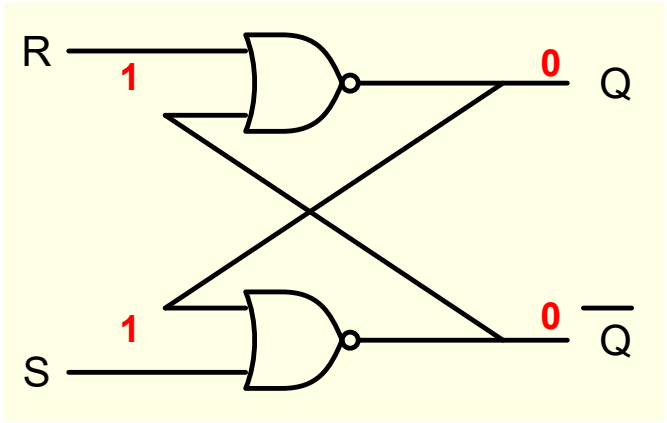
$Q = 0; \overline{Q} = 1$ Reset State

S	R	Q	$\overline{Q}$	State
1	0	1	0	SET
0	1	0	1	RESET

HOLD State

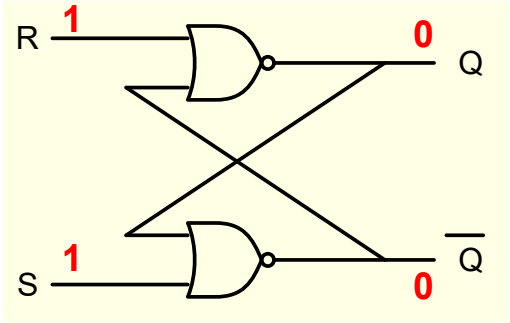


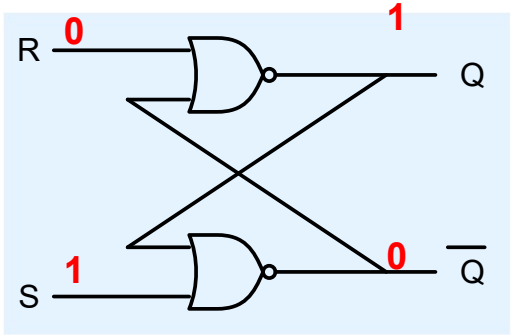
S	R	Q	$\overline{Q}$	State
1	0	1	0	SET
0	1	0	1	RESET
0	0	Q	$\overline{Q}$	HOLD
1	1	0	0	INVALID

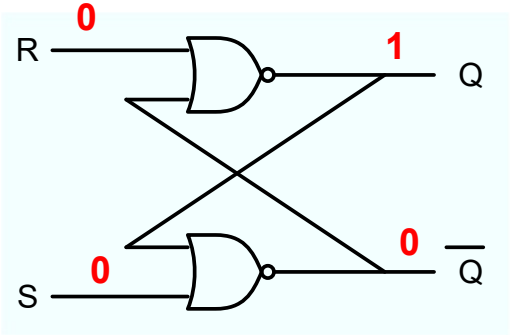


Both the outputs are well defined and 0. the first problem is that we do not get complementary output.

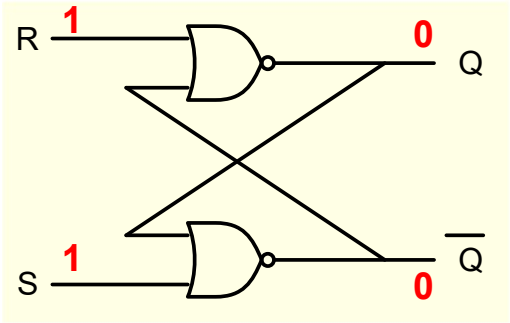
A more serious problem occurs when we switch the latch to the hold state by changing RS from 11 → 00 . Suppose the inputs do not change simultaneously and we get the situation 11 → 01* → 00

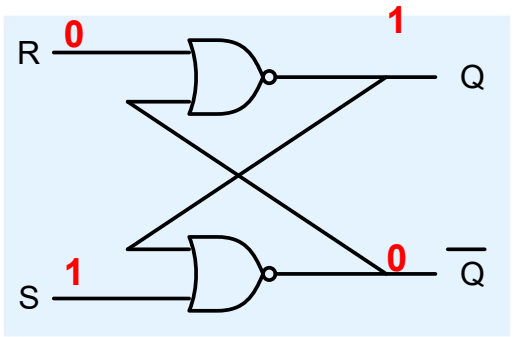


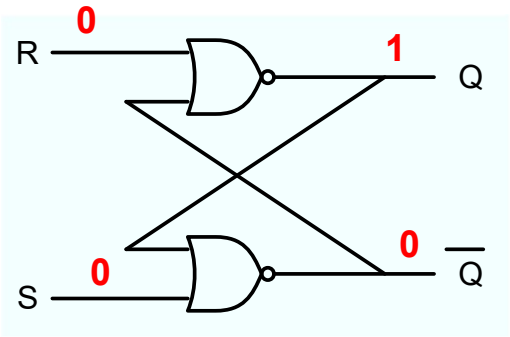




Q = 1

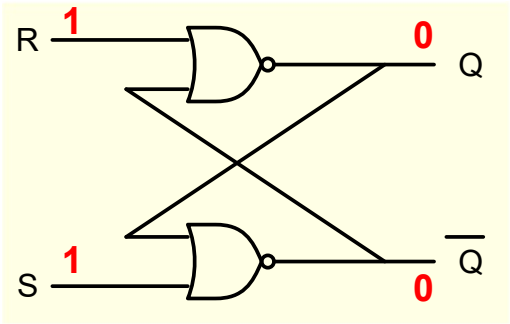


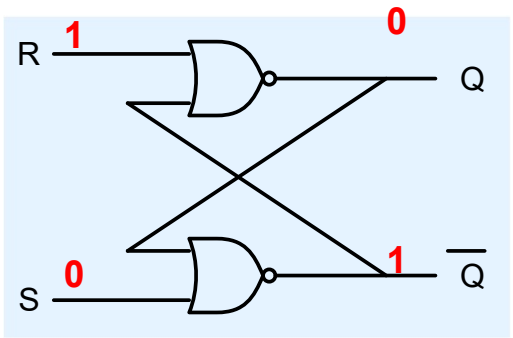


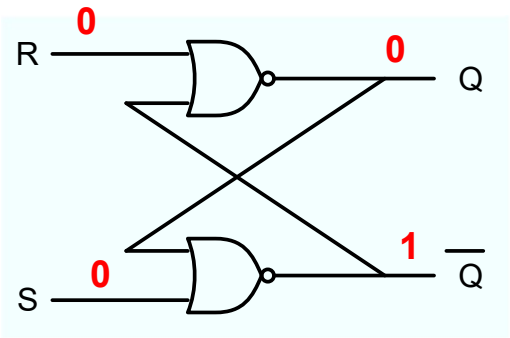


Q = 1

Suppose the inputs change as RS = 11 → 10* → 00



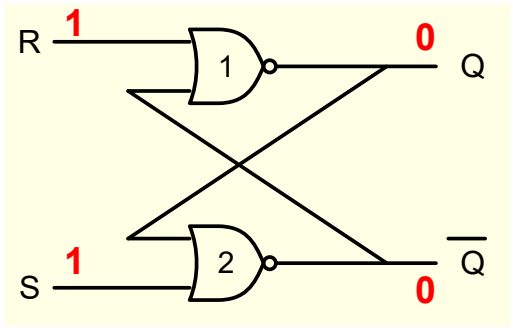


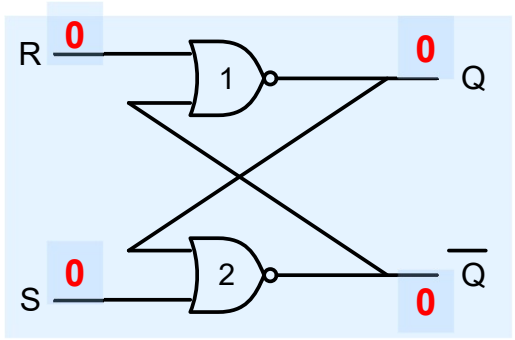


Q = 0

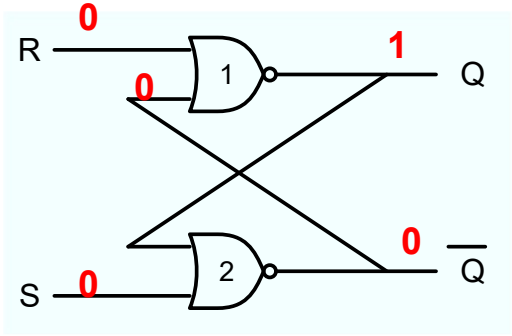
So although output is well defined when we apply RS = 11, it becomes unpredictable once we switch the latch to hold state by applying RS = 00. That is why RS = 11 is not used as an input combination.

The error can occur also due to unequal gate delays.



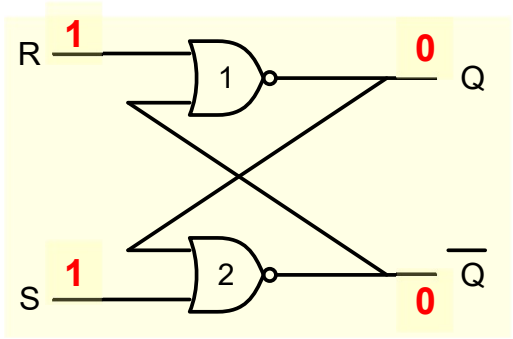


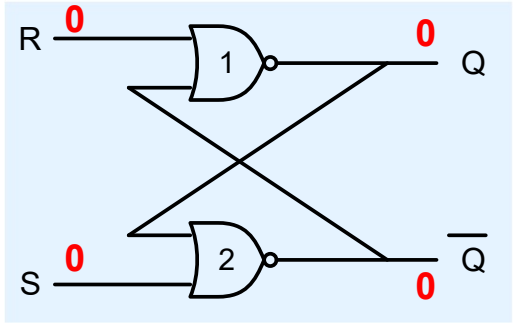
Suppose gate-1 is faster

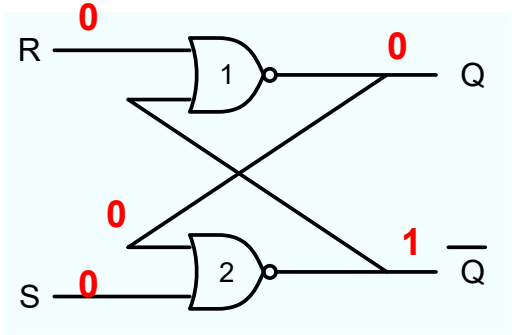


Q = 1

On the other hand suppose that gate-2 is faster.



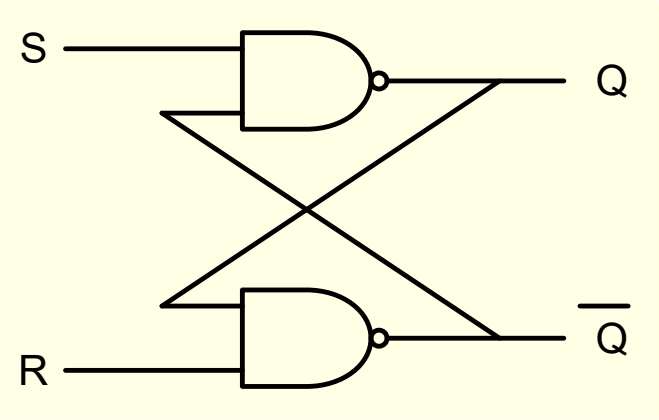




Again the output is unpredictable in general

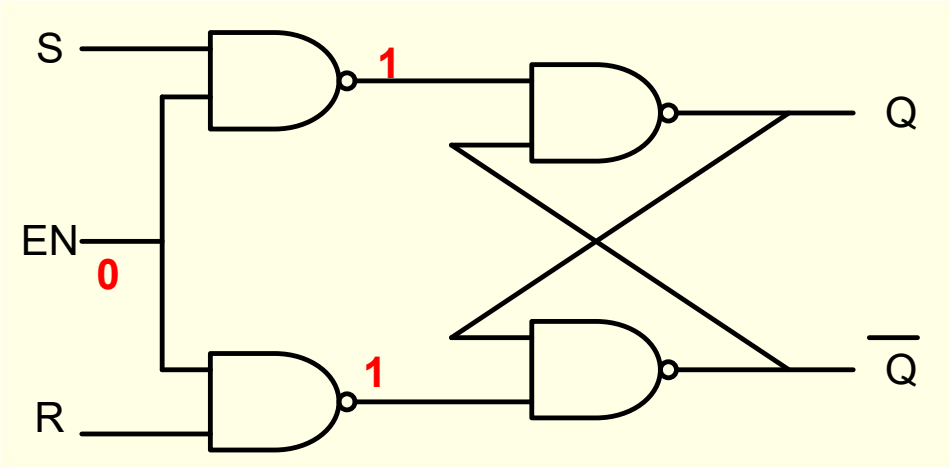
Q = 0

NAND Latch

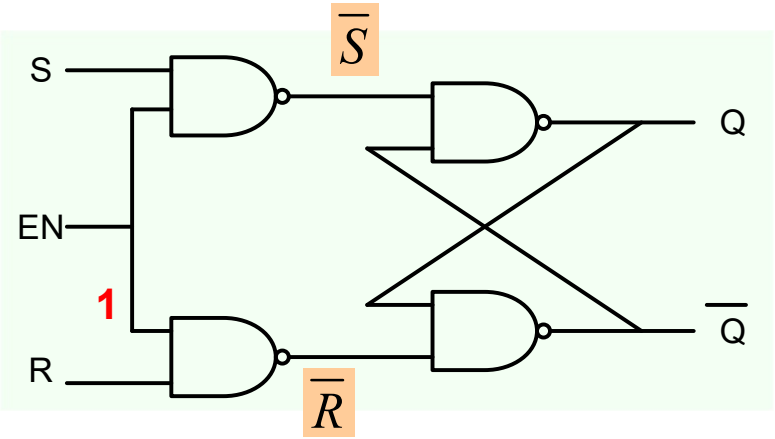


S	R	Q	$\overline{Q}$	State
0	1	1	0	SET
1	0	0	1	RESET
1	1	Q	$\overline{Q}$	HOLD
0	0	1	1	INVALID

RS NAND Latch with Enable

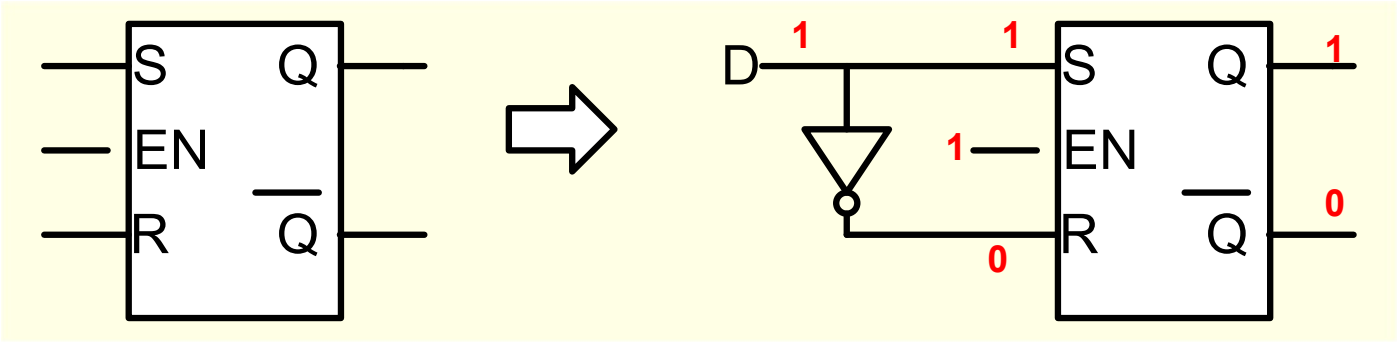


Hold State

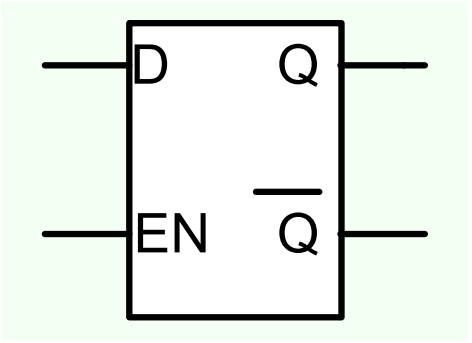


Enable	S R	Q $\overline{Q}$	State
0	x x	Q $\overline{Q}$	Hold
1	1 0	1 0	Set
1	0 1	0 1	Reset
1	0 0	Q $\overline{Q}$	Hold
1	1 1	0 0	Invalid

D latch

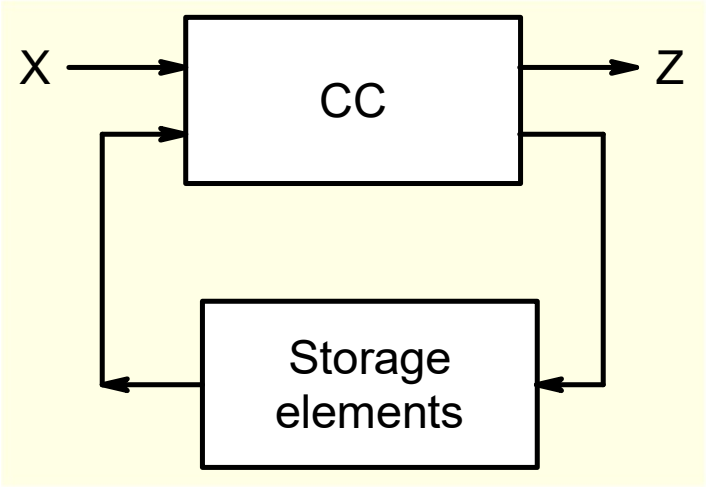


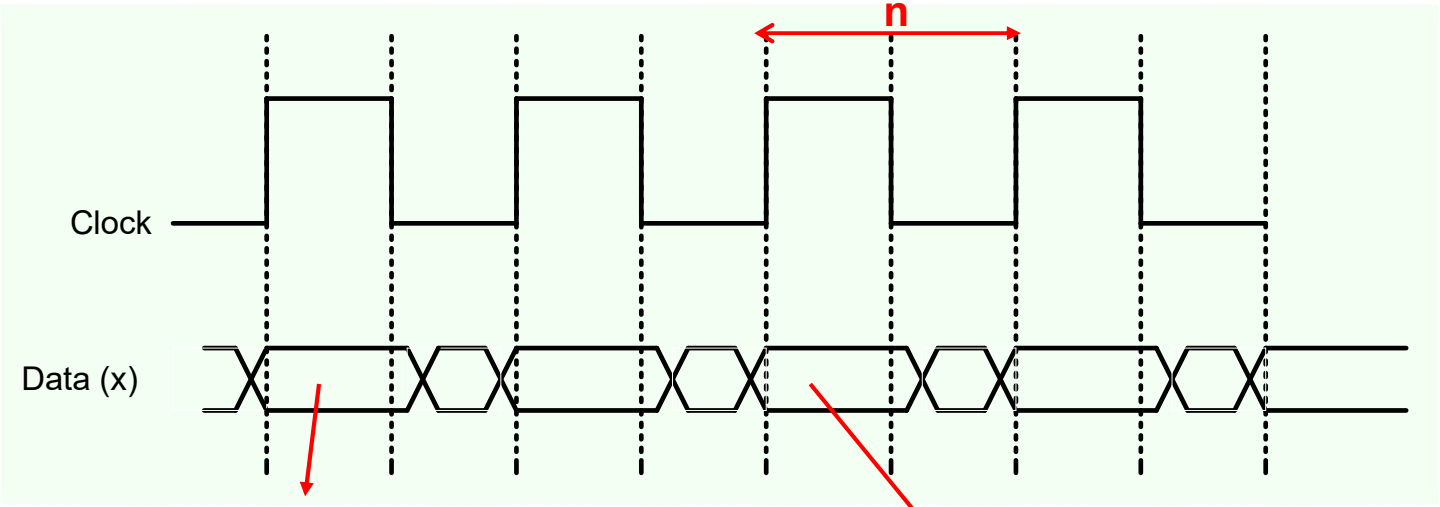
Enable	S	R	Q	$\overline{Q}$	State
0	x	x	Q	$\overline{Q}$	Hold
1	1	0	1	0	Set
1	0	1	0	1	Reset
1	0	0	Q	$\overline{Q}$	Hold
1	1	1	0	0	Invalid



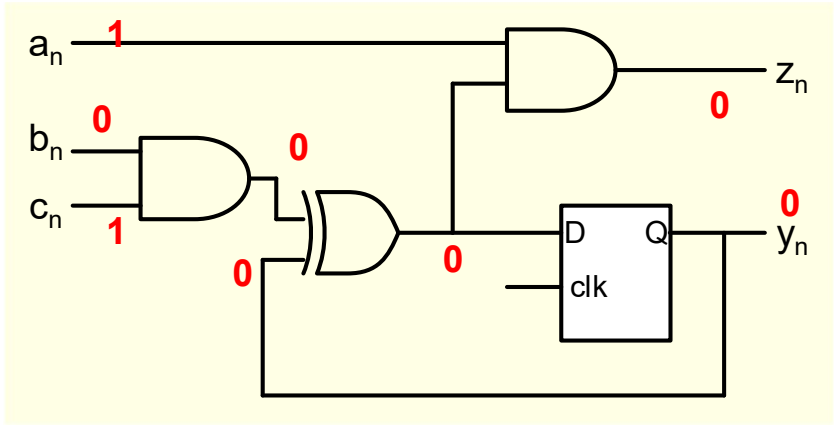
If EN = 1 then Q = D otherwise the latch is in Hold state

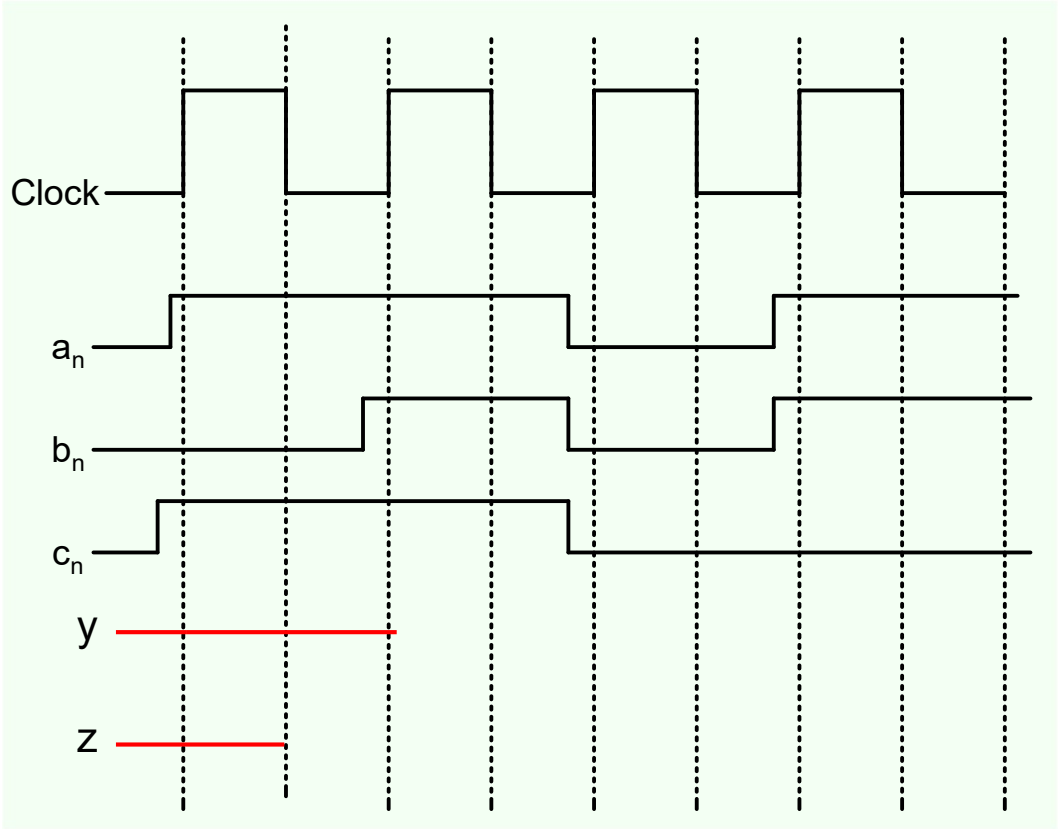
Synchronous Sequential Circuits



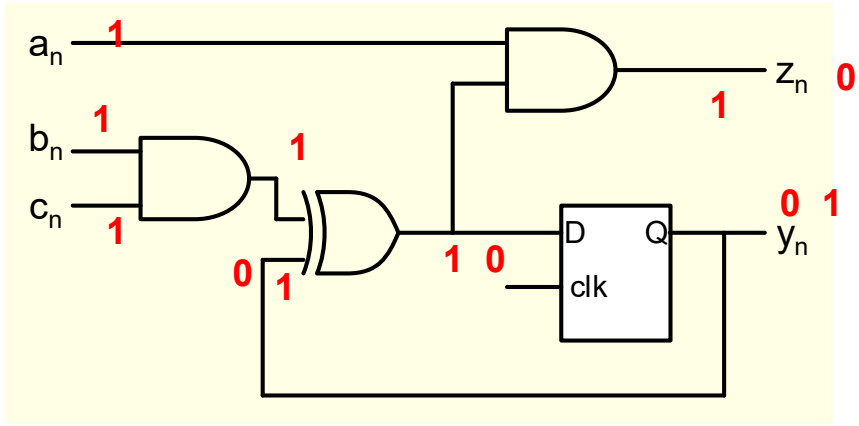


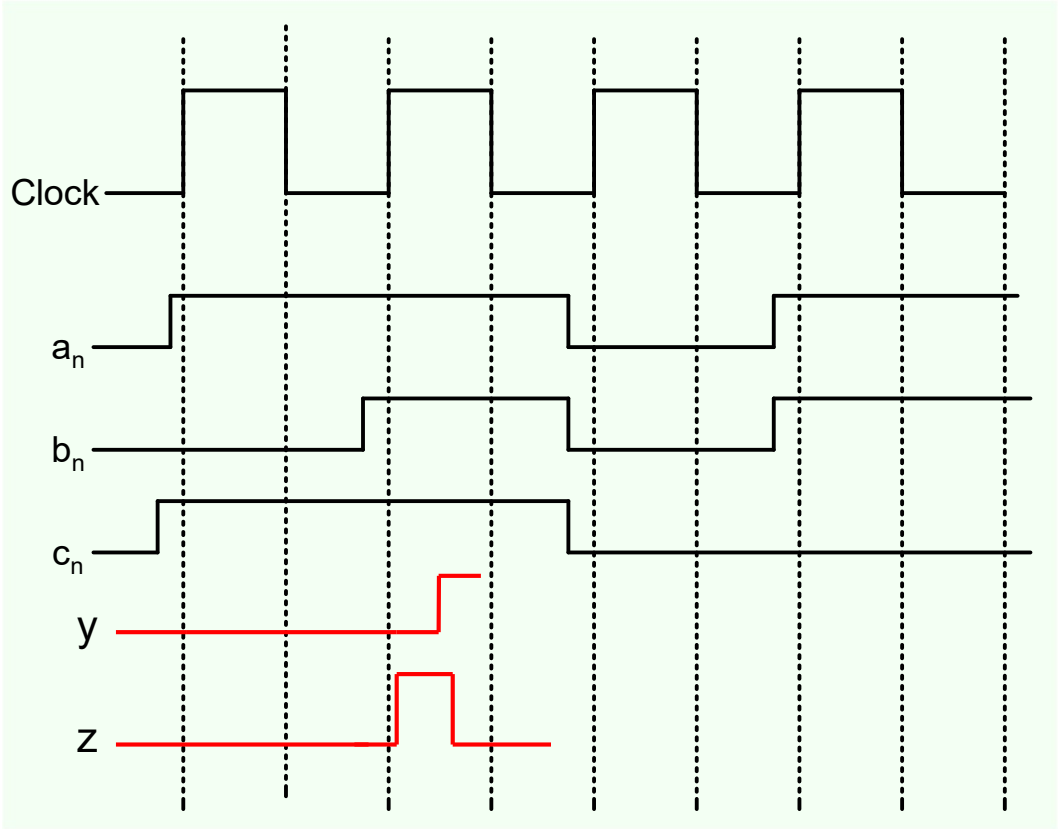
Example



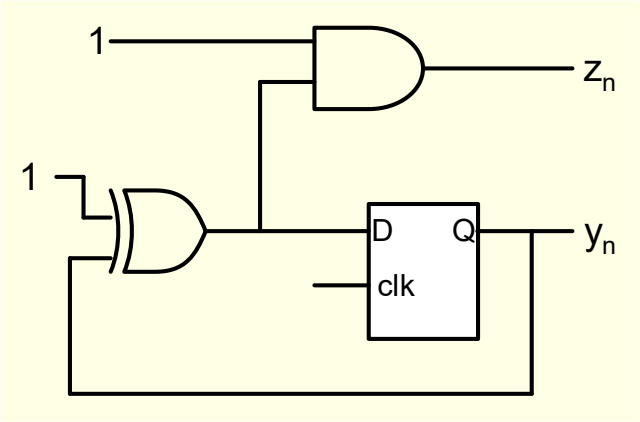


Example

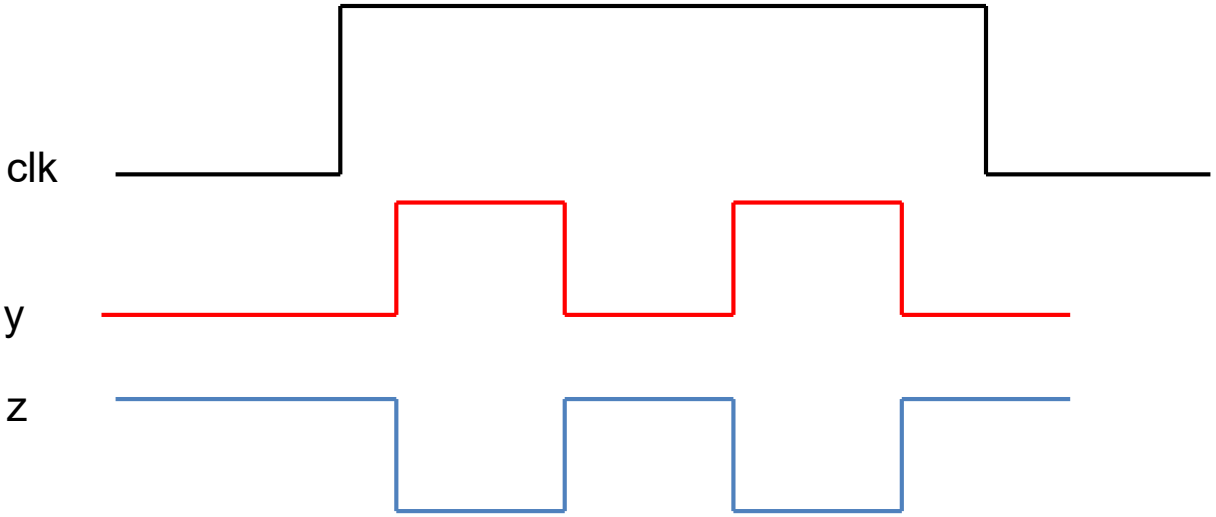




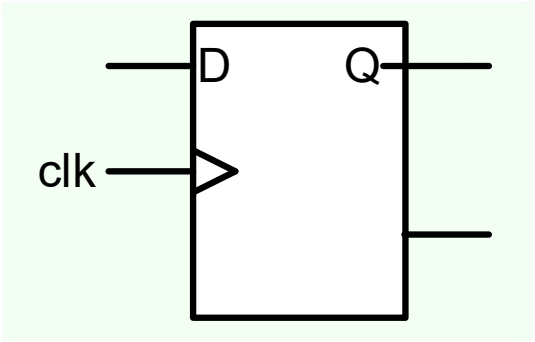
Problem with Latch

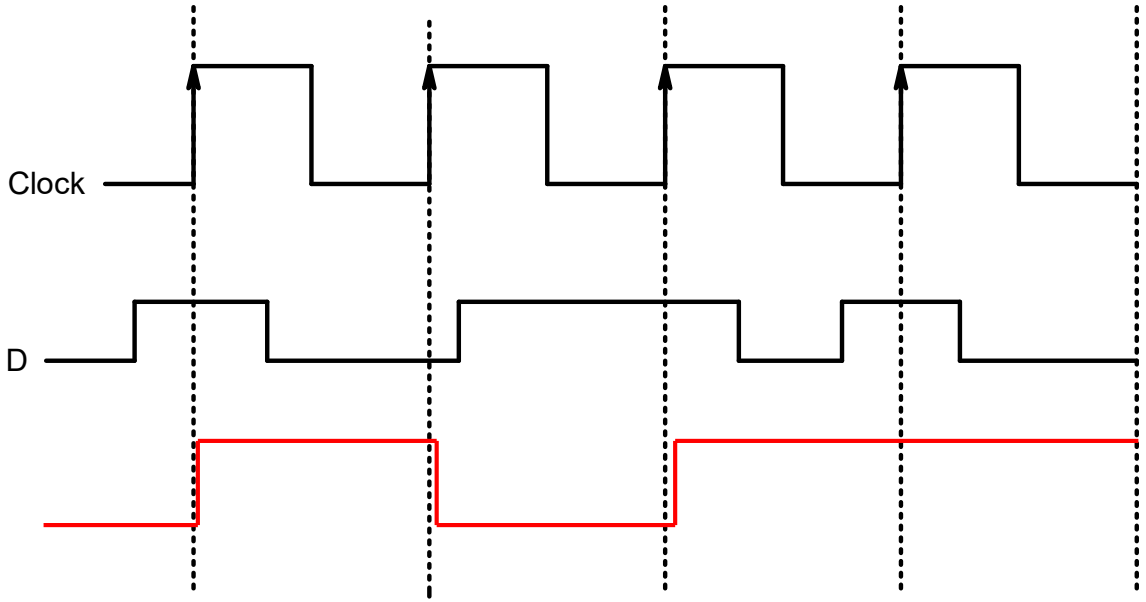


Circuits are designed with the idea there would be single change in output or memory state in single clock cycle.



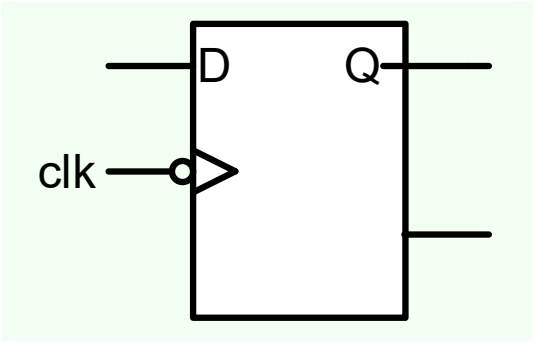
Edge Triggered Latch or Flip-flop

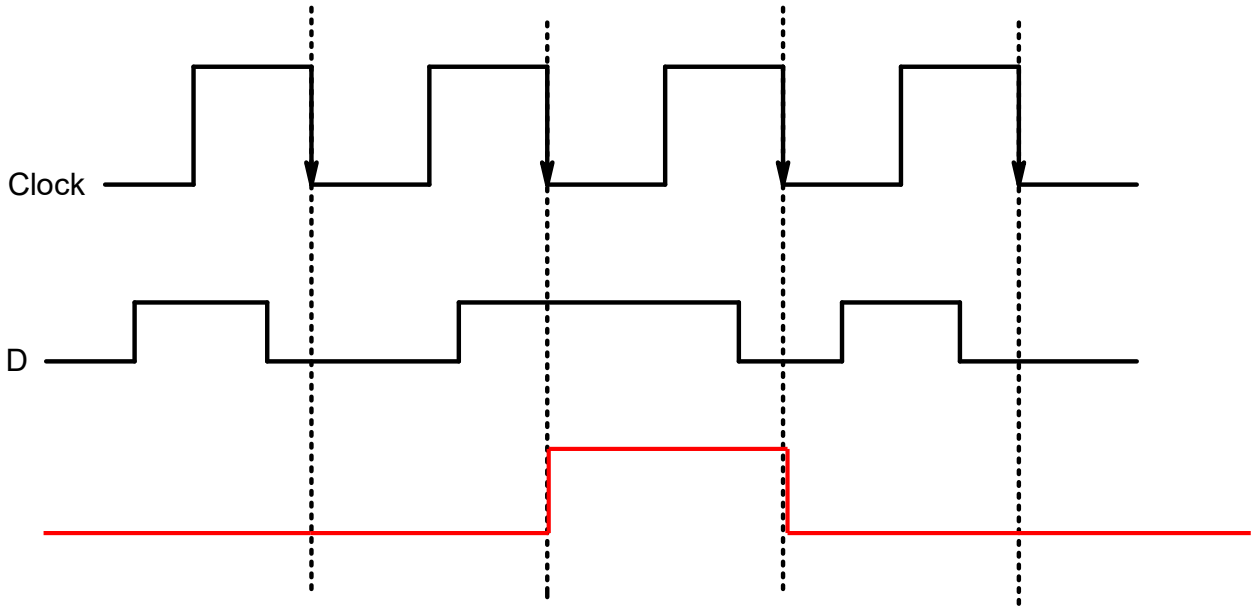




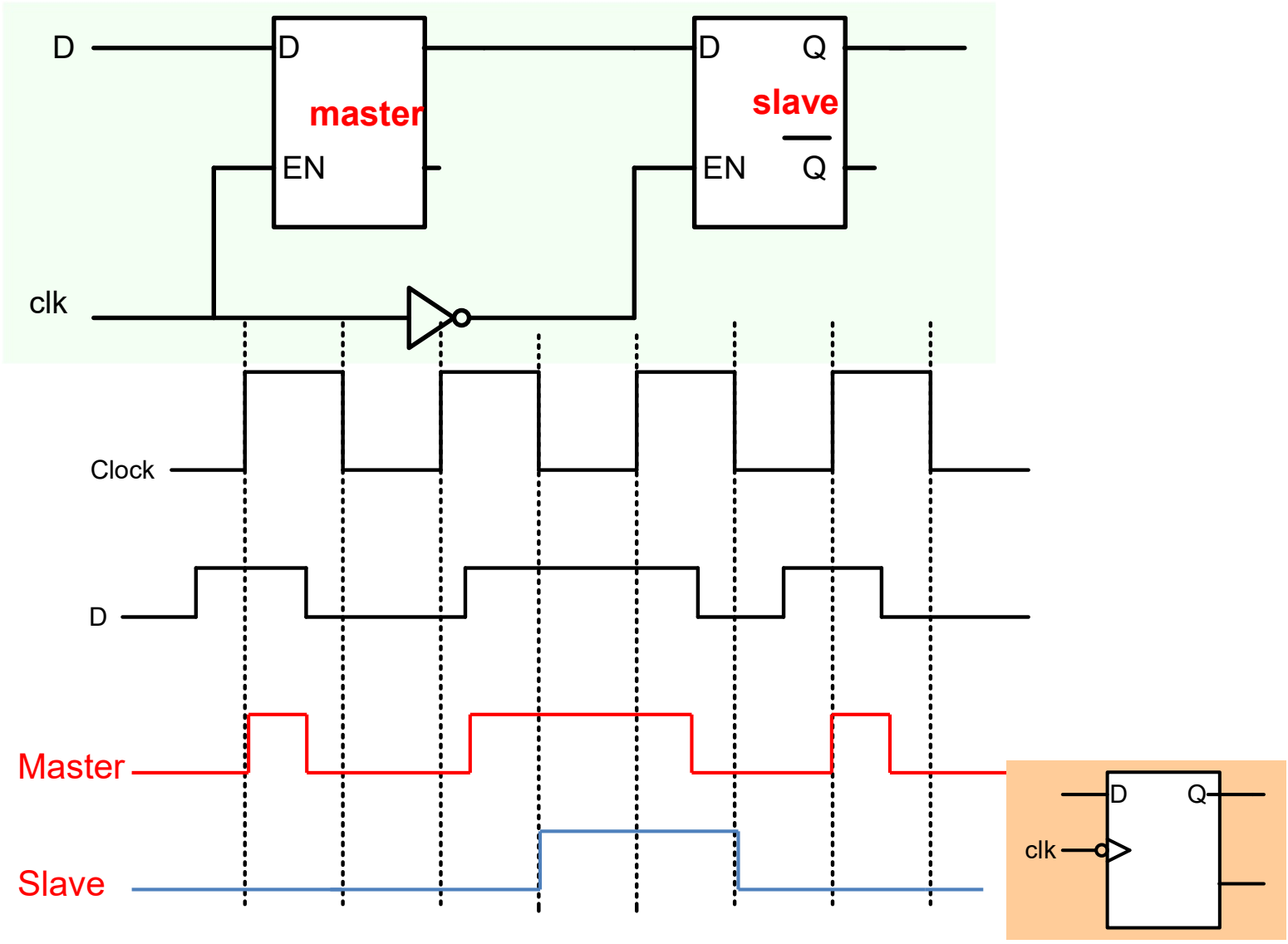
Positive edge triggered flipflop

Negative Edge Triggered Latch or Flip-flop

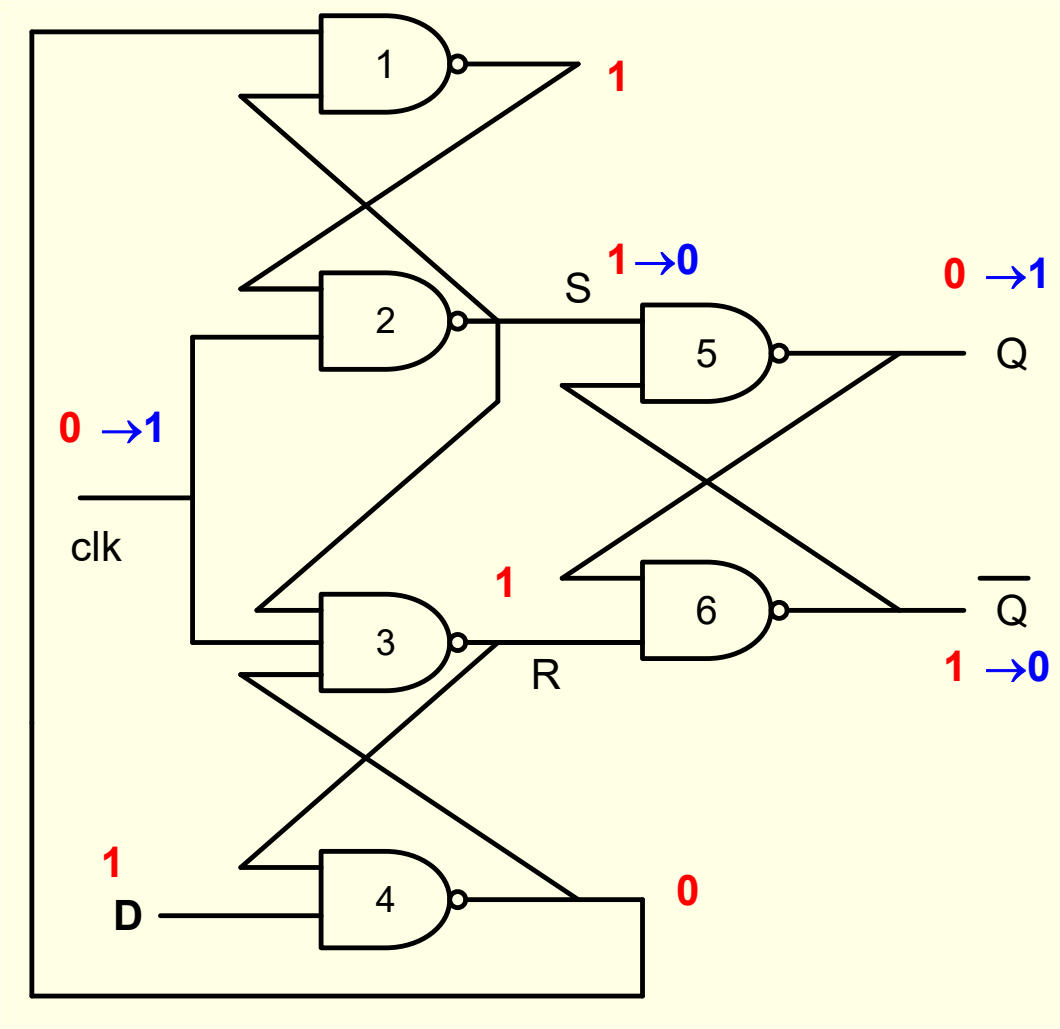




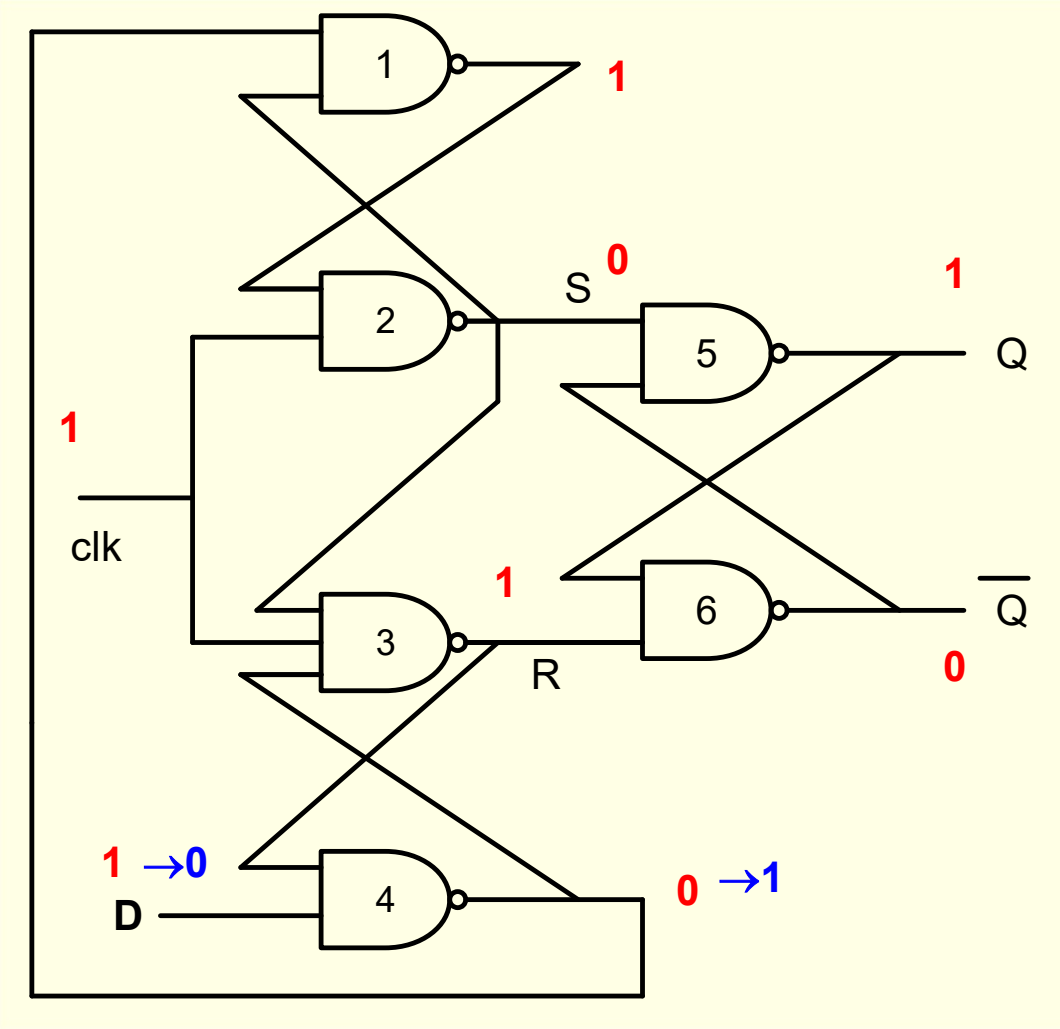
Master-Slave D Flip-flop



Positive edge triggered Flip-flop

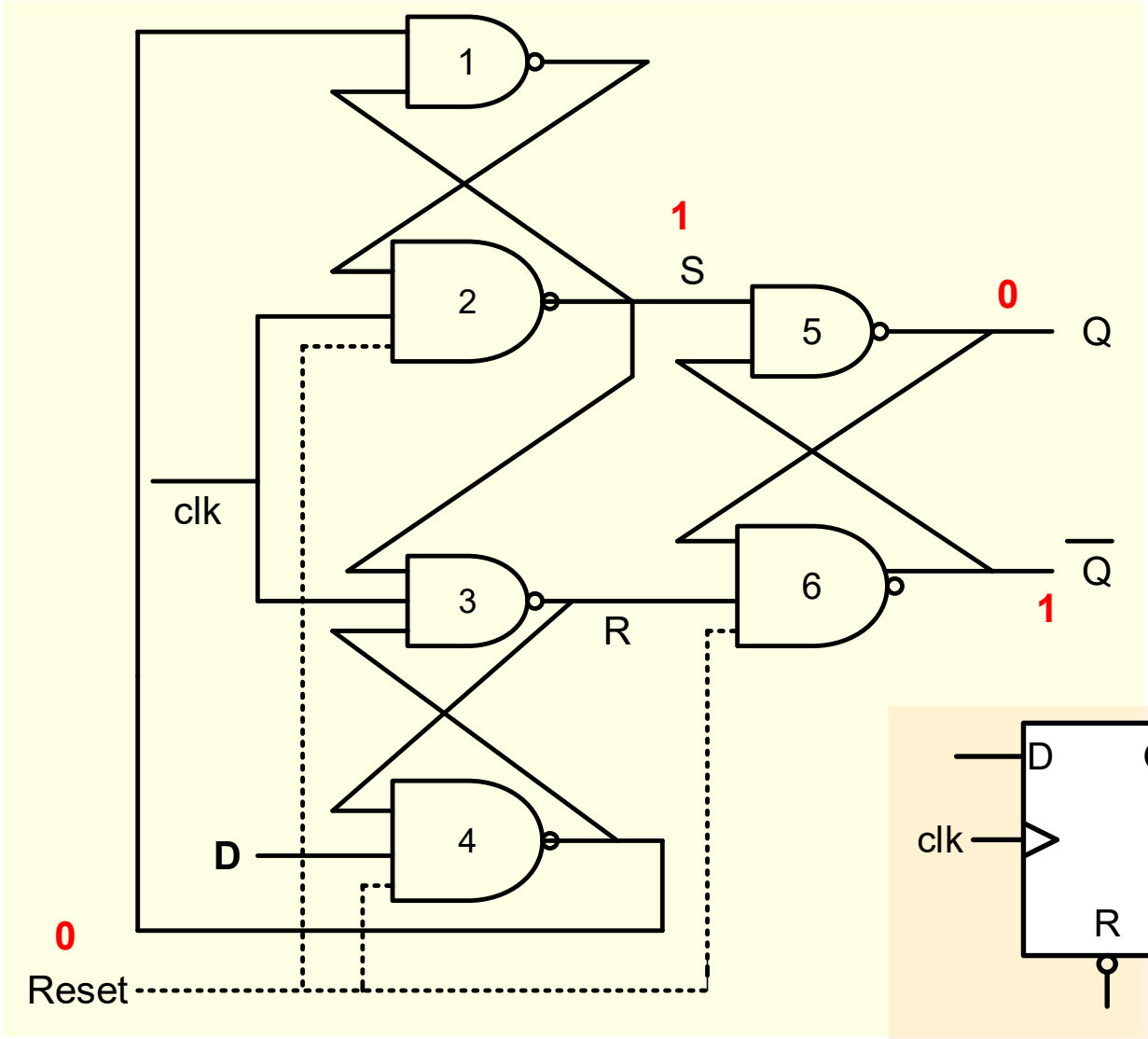


Positive edge triggered Flip-flop



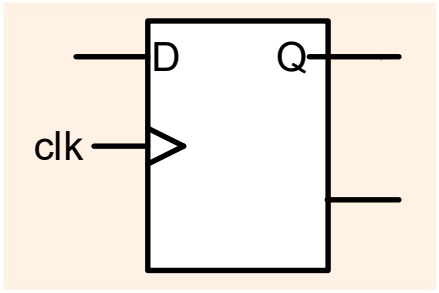
A change in input has no effect if it occurs after the clock edge

Positive edge Triggered Flip-flop with Asynchronous Reset



Characteristic table

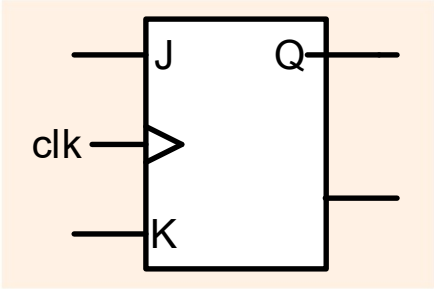
Given a input and the present state of the flip-flop, what is the next state of the flip-flop



Inputs (D)	Q(t+1)
0	0
1	1

$$Q(t+1) = D$$

JK Flip-flop

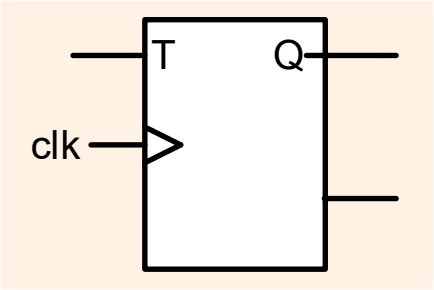


Inputs J	K	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

$$Q(t+1) = \overline{Q(t)}.J + Q(t).\overline{K}$$

→**Characteristic equation**

Toggle or T Flip-flop



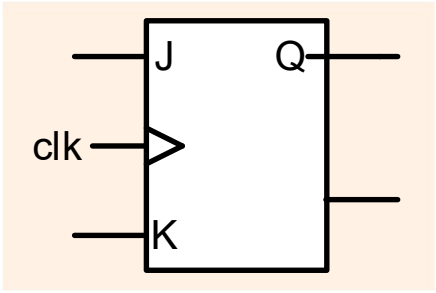
Inputs (T)	Q(t+1)
0	Q(t)
1	$\overline{Q(t)}$

$$Q(t+1) = \overline{Q(t)}.T + Q(t).\overline{T}$$

Excitation Table What inputs are required to effect a particular state change

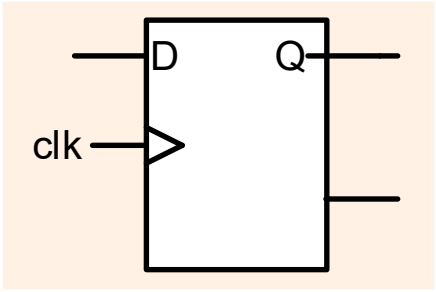
		Inputs
Q(t)	Q(t+1)	T
0	0	0
0	1	1
1	0	1
1	1	0

Excitation Table



J	K	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

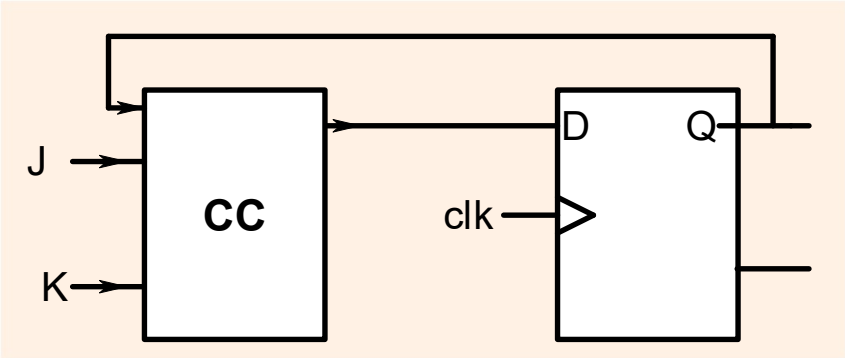
Q(t)	Q(t+1)	Inputs J	Inputs K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0



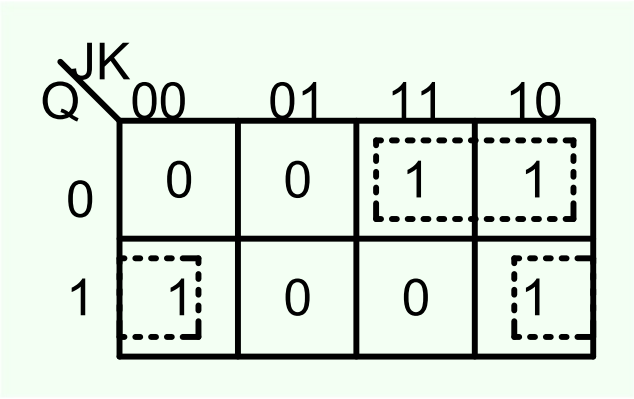
D	Q(t+1)
0	0
1	1

Q(t)	Q(t+1)	Inputs D
0	0	0
0	1	1
1	0	0
1	1	1

Convert a D FF to JK FF



J	K	Q(t+1)	D
0	0	Q(t)	**Q(t)**
0	1	0	**0**
1	0	1	**1**
1	1	$\overline{Q(t)}$	$\overline{\mathbf{Q(t)}}$



$$D = \overline{Q}.J + Q.\overline{K}$$